ASCENSIONAL RATE OF PILOT BALLOONS FROM OBSERVATIONS AT PAVLOVSK, RUSSIA

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[Abstracted and discussed by W. C. Haines on the basis of a translation by A. J. Montzka from "Annalen der Hydrographie und Maritimen Meteorologie," March, 1925]

This paper gives the results of a critical study of 506 two-theodolite observations taken during the year 1923 at the Aerological Observatory at Pavlovsk, Russia. One-half of the observations were taken in the forenoon (7 a. m.) and the other half near the noon hour (1 p. m.). The weight of the uninflated balloons averaged about 75 grams. They varied in ascensional rate, several being filled to give an assumed rate of ascent as great as 220 meters per minute as determined by Hesselberg's tables.

A number of tables and figures are given in the article to show the relations existing among the various factors which determine the ascensional rate. In this abstract, Table I of the original is reproduced as Table 1; II and III as 2; VI as 3; VII as 4; Figure 3 as Figure 1.

TABLE 1.—*Mean departures, for various levels, of the actual ascensional rate of the balloons from the assumed rate for the year; also for the winter half year and the summer half year*

Altitude (km.)	Year		Winter		Summer		Altitude (km.)	Year		Winter		Summer	
	7 or 8 a. m.	1 p. m.	8 a. m.	1 p. m.	7 a. m.	1 p. m.		7 or 8 a. m.	1 p. m.	8 a. m.	1 p. m.	7 a. m.	1 p. m.
0.1	50	68	47	53	52	77	2.5	−6	−7	−9	−11	−5	−6
0.2	41	65	41	52	46	72	3.0	−7	−10	−4	−7	−9	−10
0.3	34	55	26	35	38	65	3.5	−7	−7	−8	−10	−7	−6
0.4	14	46	40	20	18	58	4.0	−11	−9	−18	−9	−9	−8
0.5	10	46	−0.3	21	15	57	4.5	−19	−7	−31	0	−16	−7
0.6	3	40	−2	12	6	51	5.0	−24	−15	−58	−3	−19	−16
0.8	−2	25	−9	−2	0.3	36	5.5	−23	−20	-----	-----	−22	−20
1.0	−3	18	−4	−7	−3	28	6.0	−29	−7	-----	-----	−29	−7
1.25	−5	6	−1	−13	−7	13	6.5	−40	−10	-----	-----	−39	−10
1.5	−7	5	−6	−14	−8	11	7.0	−54	−10	-----	-----	−54	−10
1.75	−9	−2	−6	−17	−10	3	7.5	−28	-----	-----	-----	−28	-----
2.0	−9	−5	−9	−17	−8	−1	8.0	−28	-----	-----	-----	−28	-----
2.25	−5	−8	−4	−13	−4	−6							

From Table 1 it is evident that in the lower levels even in winter the departures of the actual from the assumed ascensional rates reach large plus values. At the 100-meter level, in winter the actual ascensional rate is 24 per cent greater than the assumed, and in summer 35 per cent greater. The departures become smaller with altitude; that is, the actual ascensional rate gradually comes nearer to the assumed. In winter and in the mornings of summer the departures are smaller, the zero value being reached at the 500-meter level, whereas at the summer noon hour this value is not reached until the 2,000-meter level. Negative departures show an increase at the 5,000-meter level, which fact, the author points out, seems to agree with the lessening of the lifting power caused by the loss of hydrogen.

In the winter there is little difference in the departures in the forenoon and afternoon; also there is little difference between the winter departures and the summer morning departures. The author attributes the large values reached in the summer afternoons to thermal turbulence, or convection, due to warming up of the earth's surface by the sun, while the smaller values of winter and summer mornings he explains as due to mechanical turbulence caused by movements of air masses over the earth's surface. This explanation is borne out by Table 2, which shows that the departures vary with the wind velocity, the larger plus departures occurring with the stronger wind. The effect of wind velocity on the rate of ascent can be seen in both morning and noon hour observations in winter, whereas in the summer noon-hour observations the effect is reversed, the stronger plus departures occurring with the light winds. Here the thermal turbulence is so pronounced as to overcome the effect of the strong winds entirely. Conclusions are drawn from both tables that the effect of wind velocity on the ascensional rate is confined to the lower levels of the atmosphere where turbulence is pronounced. Above 400 to 600 meters the departures for strong as well as light winds become of the same order of magnitude. The author invites attention to the fact that the increase of wind velocity in the upper layers can be independent of the turbulence process, a condition which he and others have shown does not prevail near the surface.

TABLE 2.—*Mean departures of the actual from the assumed rate of ascent compared with the wind velocity at the 1,000-meter level, for the winter and summer half years*

Altitude (km.)	Wind velocity at 1,000 m. level							
	0–4 m. s.		5–8 m. s.		9–12 m. s.		13–16 m. s.	
	8 a. m.	1 p. m.	8 a. m.	1 p. m.	8 a. m.	1 p. m.	8 a. m.	1 p. m.
WINTER								
0.1	+14.0	+32.5	+39.7	+48.3	+57.6	+66.8	+93.0	+49.1
0.2	+14.6	+43.2	+16.4	+43.2	+39.1	+62.8	+80.3	+46.0
0.3	+5.3	+17.5	+10.8	+34.0	+23.0	+30.4	+75.3	+42.5
0.4	+6.6	+9.9	+10.9	+19.6	−14.5	+29.7	+38.1	−6.1
0.5	−3.0	+4.9	+3.5	+18.1	−15.1	+32.3	+25.2	−2.4
0.6	−12.0	−15.4	+1.4	+1.9	−20.8	+40.3	+25.5	−10.8
0.8	−3.5	−4.9	−6.0	−6.3	−21.2	+2.0	+8.0	+3.2
1.0	−8.0	−7.3	−4.6	−9.6	−13.3	−7.5	−12.0	−21.0
SUMMER								
0.1	+41.7	+81.8	+48.0	+84.6	+46.6	+65.6	+80.4	+79.7
0.2	+36.6	+77.5	+37.3	+73.6	+45.5	+71.0	+72.6	+61.7
0.3	+37.2	+72.6	+34.7	+72.1	+36.4	+58.6	+52.7	+57.8
0.4	+18.1	+56.7	+16.2	+62.6	+14.5	+66.9	+33.2	+36.8
0.5	+14.4	+58.8	+14.5	+62.0	+11.1	+71.0	+20.0	+33.2
0.6	+10.7	+52.1	+6.8	+68.3	−2.7	+66.4	+11.8	+8.3
0.8	+2.0	+30.7	+5.4	+50.2	−10.3	+49.0	+6.1	+0.2
1.0	−3.4	+32.1	−3.6	+34.7	−7.6	+27.4	+5.1	+19.5

From Table 3 it is apparent that, especially in the morning hours, the balloons show a higher ascensional rate with winds from the northerly quadrants than with winds from the southerly. But this applies only to the lower levels, below 400 or 500 meters. The reason for this given by the author is that the larger temperature lapse rate of northerly winds near the surface in comparison with that of the southerly winds is the predominating factor.

TABLE 3.—*Mean departures of the actual ascensional rate from the assumed, for different wind directions for various levels up to 1,000 meters*

Wind direction	Altitude (km.)							
	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0
MORNING								
NE	56	49	35	16	6	4	−9	−3
SE	31	29	19	4	0	1	3	2
SW	45	37	30	10	9	2	−1	−7
NW	61	50	44	20	14	3	0	−4
AFTERNOON								
NE	54	56	48	50	51	44	29	19
SE	54	54	47	36	29	35	16	15
SW	78	70	52	48	47	42	28	26
NW	70	70	67	51	52	40	24	14

In the morning hours, at least, the ascensional rate attains larger values in periods of falling temperature, especially at their beginning, than in periods of rising temperature. At the noon hour this difference disappears. This is shown by Table 4. From the rising periods there was separated a period of little change in temperature, given in the table as the normal. The values for this normal period are smaller than those for the cold, and larger than those for the warm period; and these normal values come close to the values for the year given in Table 1.

TABLE 4.—*Mean departures of ascensional rate for falling temperature periods (−A and −B) and for rising temperature periods (A and B) for various levels up to 1,000 meters. The values for Group A are for the beginning of the periods and those of B for their ends*

Altitude (km)	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0
	Morning							
−A	58	59	46	22	18	7	−1	10
−B	55	44	39	21	15	10	8	11
+A	50	27	21	8	6	2	−6	−6
+B	45	33	29	7	7	−6	−8	−3
Normal	59	43	36	12	9	2	−2	−10
	Afternoon							
−A	87	77	60	59	60	46	39	28
−B	54	53	48	38	37	35	25	20
+A	57	58	47	32	32	27	15	14
+B	84	66	53	46	51	44	41	26
Normal	70	67	58	49	48	44	20	15

From the foregoing and other facts brought out in his study, the author concludes that the ascensional rate of balloons is affected not only by the aerodynamical qualities of a given balloon but also by the weather conditions to a large degree. In view of this fact he thinks the investigation of all conditions which are connected with the movement of pilot balloons is doubly important, as this leads not only to a fuller development of the theory of methods of research into the velocity of air streams, but also indicates a procedure which enables us to express a characteristic of the atmospheric conditions of the air strata.

The author compares the results of his investigation with the results obtained in this country. (*1*) He finds that the departures as given in an article on the ascensional rate of balloons published by the reviewer are much smaller than those obtained from the observations taken in his country. For an explanation he gives the following: The conditions of the movements of a balloon in the atmosphere are mostly determined by the resistance offered by the atmosphere. According to the experiment by Prandtl (*2*) the coefficient of resistance of the balloon does not bear a constant relation to the velocity of the balloon but varies with the so called "Reynold's number," $R = \frac{\rho v D}{\eta}$ in which ρ is the density of the air; v, the velocity of the balloon; D, the diameter of the balloon; and η, the molecular viscosity of the air; and it also varies with the air conditions. It is shown that the greatest difference between the coefficient of friction for still and turbulent air occurs when the Reynolds' number is between 100,000 and 200,000. Hesselberg has shown that for pilot balloons it is enough to assume that the Reynolds' number is proportional to the lifting power of the balloon. Therefore from Prandtl's results it might be expected that the difference in the movements of the balloons in still and turbulent air would vary with the free lift of the balloon. This is shown by Figure 1. The greatest departures occur with balloons with a 200-gram lift as used in Russia. The balloon with a 150-gram lift shows smaller departures, and the smallest departures occur with balloons of about 70 grams free lift. From the foregoing the author concludes that by taking observations with one theodolite it would be better to use a free lift of only 70 or 80 grams. In order to get high enough ascensional rate he suggests using balloons of smaller weight.

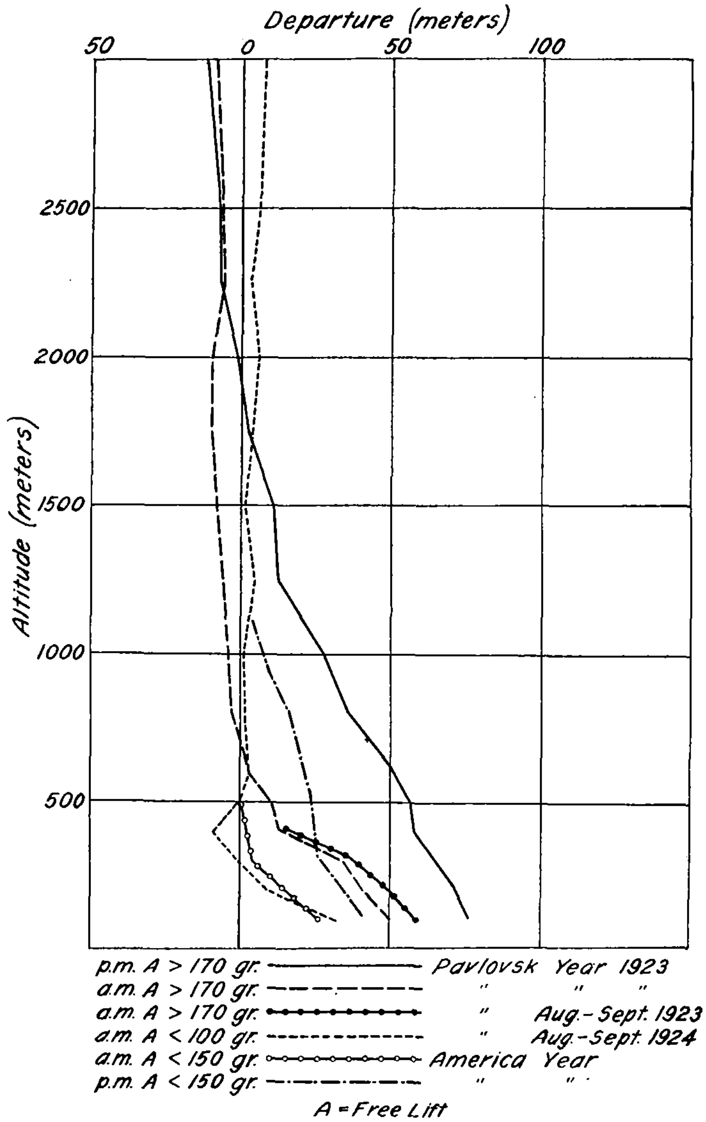

FIG. 1.—Curves showing the relation of the mean departures of the ascensional rate from the assumed, with the free lift of the balloon

DISCUSSION

In the study of the ascensional rate of pilot balloons referred to by the author, the reviewer made no attempt to show whether or not a relation exists between the ascensional rate of the balloon and the velocity of the wind, the primary object of the study being to verify the ascensional rate formula in use. Since that time, however, the reviewer has made a careful study of two-theodolite observations in order to determine the effect of wind velocity on the ascensional rate. It is of interest to give the results of this study here as they verify the results obtained by Moltschanoff in this connection.

In this study 418 two-theodolite observations made at various aerological stations in the United States were selected. The only criterion used in the selection was that they be taken early in the morning so as to exclude the effects of thermal convection. Consequently only observations taken before 8 a. m. were used. The balloons weighed 25 to 35 grams and were filled to give an ascensional rate of 180 meters per minute or to a free lift of from 120 to 130 grams, depending upon their weight. The velocity of the wind was correlated with the ascensional rate for each of the first four minutes of the observations, i. e., the velocity of the wind at the end of the first minute was correlated with the ascensional rate during the first minute, the velocity of the wind at the end of the second minute was correlated with the ascensional rate of the balloon during the second minute, etc. There was found to be a direct relation between the ascensional rate and the wind velocity during the first minute. The second minute showed a mere suggestion of a relation and the third and fourth minutes no relation whatever. The correlation coefficients and probable errors for the first, second, third, and fourth minutes were found to be $+0.507 \pm 0.024$, $+0.172 \pm 0.032$, $+0.012 \pm 0.033$, and $+0.008 \pm 0.033$.

It may be of interest also to know that the average ascensional rates for the first four minutes were, 198.4, 180.5, 178.0, and 179.1 meters per minute, respectively, and the standard deviations from these averages were 18.7, 15.8, 16.1, and 15.6 meters, respectively.

It is noted that the results of this investigation are in close agreement with those given by Moltchanoff with balloons of approximately the same free lift. Investigations of the ascensional rate of pilot balloons (*3*) made by Capt. B. J. Sherry are also in accord with the results obtained by Moltschanoff in so far as the effect of wind velocity on the ascensional rate is concerned.

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THE WIND FACTOR AND THE AIR MAIL SOUTHWARD FROM KANSAS CITY

By JOHN A. RILEY

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The Air Mail route southward from Kansas City extends first in a west-southwesterly direction to Wichita, thence southward to Oklahoma City, and from there slightly east of south to the Dallas-Fort Worth landing field midway between these two cities. The distance from Kansas City to Wichita is approximately 180 miles, Wichita to Oklahoma City 155 miles, and Oklahoma City to Dallas-Fort Worth 190 miles. The southbound mail leaves Kansas City at 11:20 a. m. and arrives at Dallas-Fort Worth at 5:40 p. m. The northbound mail leaves Dallas-Fort Worth at 8 a. m. and arrives at Kansas City at 2.15 p. m. This schedule calls for a speed of about 90 miles per hour in each direction.

In dealing with the wind factor in flight it is generally recognized among flying men that the normal state of the air is one of more or less rapid movement, subject to frequent changes of speed and direction. And although the wind is scarcely ever strong enough to prevent a flight it is sufficient to affect schedules by causing delays. The wind also tends either to reduce or to increase the average speed of flight and this effect increases as the velocity of the wind approaches the speed of the craft.

When we know the speed and direction of the wind and the cruising speed of the craft the resultant speed is readily computed. We first find the angle the craft must make with the course to overcome the effect of drift. This is called the β angle; the angle between the wind and the course is the a angle. β is found by the formula,

$$\sin \beta = \frac{S_w}{S_a} \sin a$$

in which S_w and S_a are the wind speed and the craft speed, respectively. In flying where no landmarks are visible, as above clouds or over water surfaces out of sight of land, this angle must be computed or estimated. After it is obtained the resultant speed of craft is found by the formula [1]

$$S_r = S_a \cos \beta \pm S_w \cos a$$

Figure 1 represents the surface winds at Broken Arrow. It is based on a five-year period of continuous hourly records. The average speed and the percentage frequency of the eight directions are shown.

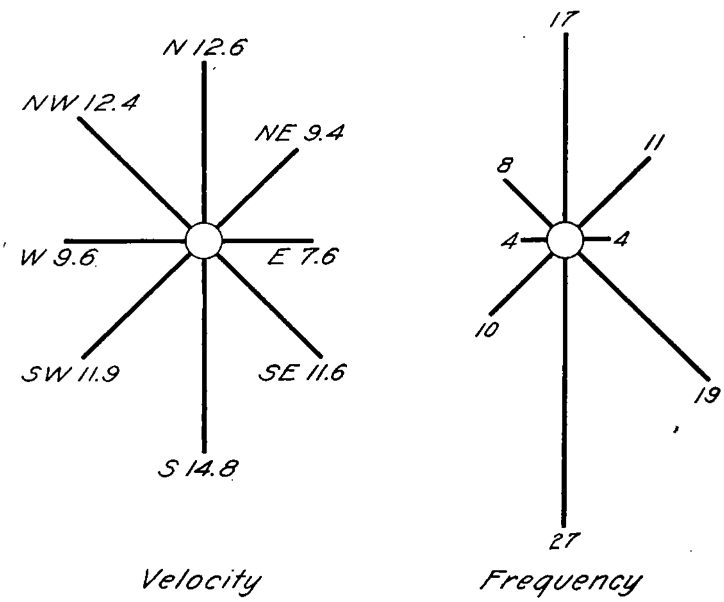

FIG. 1.—Average annual velocity (m. p. h.) and percentage frequency of surface winds, Broken Arrow, Okla., based on continuous automatic records

[1] Graphs for readily obtaining these data as well as other information of practical value in aerial navigation may be found in a paper "The weather factor in aeronautics," by Dr. C. L. Meisinger, who was until his death a pioneer in aeronautical meteorology. (Mo. Wea. Rev., Dec., 1920.)